

ON THE
ALKALINE PERMANGANATES

AS

TESTS OF THE SANITARY CONDITION OF
WATER AND AIR, AND AS PURIFIERS OF THE
SAME, WITH THE VIEW OF SHOWING THEIR
TRUE CHEMICAL POSITION AND VALUE,
AND POPULARIZING THEIR EMPLOYMENT.

INAUGURAL DISSERTATION
FOR THE ATTAINMENT OF THE DEGREES

OF

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BY

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ROSTOCK: ADLER'S HEIRS.

1868.

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Part I.

Permanganate of Potash as a popular qualitative Test for decomposing organic matter in potable water and as a purifier of the same.

It is now universally admitted that all species of impurities or foreign matters, whether organic or inorganic, to which water is subject, may justly be regarded as injurious to health; but it is especially the former class of substances which, on meeting with unwholesome atmospheric or other influences, give rise to those sudden visitations of disease, which under the forms of diarrhoea, fever, cholera etc. carry off so many victims. Some inorganic impurities in the long run undoubtedly prove prejudicial to health, but they seem incapable of producing the serious symptoms which characterize zymotic diseases. To defects in the composition of water, as regards its inorganic constituents, have been ascribed various constitutional affections, of which the 'goître' is one of the most remarkable. Such evil effects are, however, slow

and insidious compared with those caused by organic contaminations, which, under certain circumstances, act very much like poisons, or those emanations from organized beings on which contagion depends. Like the latter, whose morbid influence Liebig has so clearly shown to be the result of a certain state of transformation, which acts on the blood — itself an extremely complex compound, in a condition of constant metamorphosis — after the manner of a ferment, organic impurities must be regarded rather as exerting a certain amount of morbid force, than as constituting as given volume of positively deleterious matter. Hence, extremely minute quantities taken into the system are capable of producing very extensive mischief.

The most dangerous kinds of impurities, then, are those of organic origin. They occur either in a state of solution or in the solid form. The former being invisible even with the aid of the microscope are the most to be feared, especially as they are generally accompanied by the presence of carbonic acid and alkaline nitrates, the results of decomposition, which, by communicating a sparkling appearance and cooling taste, render those waters which contain them deceptively agreeable to the palate.

About the year 1853 Professor Forchhammer in a communication to the Royal Society of Science of Copenhagen suggested that advantage might be taken of the action of organic matter in a state of change on the color of permanganate of potash for the detection of dissolved organic impurities in water. In

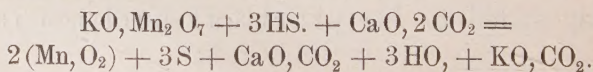
1856 Mr. Coudy first caused an agitation upon this subject in England by urging on the attention of Professor Hofmann (then in London) and since that (notwithstanding the slight errors to which it is liable through the presence of protesalts of iron, and its having failed as a volumetric test), permanganate of potash has become the popular water test of the day.

The efficacy of permanganate of potash as a test for potable water was confirmed and ably illustrated by Monsieur Emile Monnier in a paper read before the 'Academie des Sciences'¹⁾. This gentleman found that the action of permanganate of potash on organic matter in water, which at ordinary temperatures proceeds very slowly, at degrees of heat varying from 70° to 75° C. takes place with great rapidity. By operating on equal volumes of various samples of water at a fixed temperature he was enabled to arrive at a comparative idea of their relative impurity — as for instance he found that the waters of the Bièvre contained nearly ten times as much organic impurity as the Seine at Bercy.

But the action of the permanganates is not limited merely to the testing of water for organic impurities; the properties possessed by those substances, of rapidly decomposing organic matter, and making manifest to the eye their effects, render them admirably suited to the practical purification of

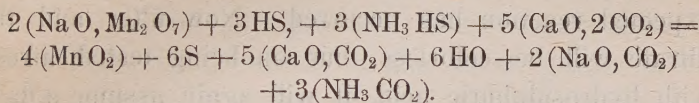
¹⁾ 'Comptes Rendus' Vol. I, page 1084.

water employed for drinking, cooking and general domestic purposes. Composed of oxygen in combination with manganese, the mildest and most wholesome of the metals, and one or other of the alkalies, the permanganates, especially permanganate of potash, can hardly be supposed capable of proving injurious even when, from carelessness or haste, a trace of them in solution or a minute portion of binoxide of manganese in suspension may remain in the water treated; for it has recently been shown that manganese is very probably one of the normal constituents of the blood. The nature of the reaction which takes place between permanganate of potash and organic matter is, moreover, such, that when they are used with caution, and not in excess, the whole of the metallic ingredient present is separated by precipitation in the solid form, leaving in the water only the small trace of alkali which had been in combination with it. As most waters, by reason of a certain portion of carbonic acid which they contain, hold in solution, in the form of bicarbonate, a small quantity of carbonate of lime, the presence of this free alkali is rather an advantage than the contrary, since by neutralizing the excess of carbonic acid, it converts the more soluble bicarbonate into a less soluble carbonate, which then subsides as a deposit, leaving an alkaline carbonate in its place, viz^t:

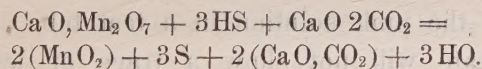


Or where sulphide of ammonium from decom-

posing organic matter is also present with hydrosulphuric acid and bicarbonate of lime, carbonate of ammonia will be left in solution, together with the other alkaline carbonate, viz^t: (supposing permanganate of soda used)



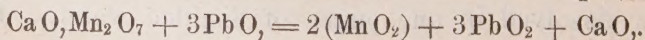
In special cases where the presence of alkaline matter might be objectionable, permanganate of lime may be employed instead of permanganate of potash. When this is the case, the oxide of calcium, which constitutes its base, is converted into carbonate by union with the carbonic acid held in solution by the water, and is precipitated along with binoxide of manganese and sulphur; viz^t:



Nor is this all, for the oxidizing properties which enables permanganic acid to consume organic impurities, gives it the power of removing from water those metals which are susceptible of being converted into peroxides as can be demonstrated as follows.

By shaking common white lead in distilled water and filtering a saturated solution of oxide of lead is made, which, on being tested by hydrosulphuric acid shows a black precipitate. Let then four ounces of this solution be taken and add to it two drops of a solution, consisting of two grains of permanganate of lime dissolved in one ounce of distilled water. This

mixture will not immediately lose the pink color communicated by the permanganate, but, if it be allowed to stand for about half an hour, all shade of pink will disappear and will be replaced by a brown color (binoxide of manganese) which proves that the expected reaction has occurred. Now filter and the filtrate will be colorless, but on being tested afresh with hydrosulphuric acid, it will again assume a dark tint, much less, however, than in the first instance. This is a sign that lead is still present, though in a minor degree. Recommence now with the same quantity of the solution of oxide of lead, but this time add five drops instead of two of the solution of permanganate of lime. The color imparted will be pink, somewhat deeper than in the former case. To hasten the reaction with a view to save time, heat half an ounce of the pink solution in a test tube, and filter. The filtrate will not show a trace of lead on the application of the hydrosulphuric acid. Without using heat, allow the remainder of the mixture to stand two hours. When then examined, the color will be found entirely changed from pink to brown. A portion of this may be tested for lead; the result will indicate its entire absence. The rest may be set aside without being filtered till the following day; the binoxide of manganese formed by the action of the permanganic acid will have entirely subsided carrying with it the peroxide of lead, and leaving the water free from trace of that metal. The rationale of that action is simple, viz^t:



The permanganic acid of one equivalent of permanganate of lime converts three equivalents of protoxide of lead into peroxide, and resolves itself into two equivalents of binoxide of manganese, all of which, from being in a state of solution, become insoluble, and are precipitated. Water may thus be freed from lead, which is the most poisonous of ordinary metallic contaminations, and by reactions of a similar nature from all metals capable of assuming the form of peroxides.

It is evident that by the same means water containing ferruginous impurities may be purified so as to render it fit for use in ayeing and other industrial and economic processes. The avidity which iron exhibits for oxygen makes this reaction absolutely certain.

Of all the methods of purifying water which have hitherto been in use, there is not one that, even under the most favourable circumstances, with space and time at command, can be considered of great efficacy. Filters remove suspended impurities only; boiling destroys the vitality of animal and vegetable impurities and separates carbonate of lime; the action of alum, so far as organic impurities are concerned, is more of the nature of a mere clarifying agent than that of a chemical purifier of water, in which it necessarily leaves an admixture of styptic matter, with a salt of potash or ammonia, and substitutes sulphate for bicarbonate of lime; caustic alkalies do nothing more than throw down carbonate of lime, leaving alkaline

carbonates in its place; alkaline carbonates soften water by decomposing earthy salts and precipitating earthy matters; caustic lime merely separates carbonate of lime; while even distillation itself, as ordinarily conducted, leaves water which previously contained organic matter contaminated to a certain extent with that impurity, and deprived of the oxygen which renders it palatable and wholesome.

Filtration through charcoal has no doubt considerable effect in absorbing gases, which are the products of the decomposition of organic matter; but it acts only very partially on such matter when not in a decomposing state. Hence water which has been more or less deodorized by means of charcoal, will often be found, on being allowed to stand, to become again offensive, from the further decomposition of organic matter, which the charcoal has been inadequate to remove. The presence of such organic impurities in water which has been treated by charcoal, can always be readily detected by means of permanganate of potash. Nothing proves so distinctly the superiority of this substance for purifying water as the certain and delicate way in which it discovers the imperfections of all other methods of purification, whereas no substance that I am acquainted with is capable of revealing the presence of organic matter after its use as a purifier. Permanganate of potash then not only affords a ready and efficacious means of doing what charcoal is supposed, tediously and unperfectly, to perform, but likewise of producing

changes similar to those effected by most of the other modes of purification which are usually recommended or occasionally practised. Thus it does all that alum, caustic alkalies, alkaline carbonates, and caustic lime are capable of accomplishing, while it even excels boiling in its power of removing organic matter, at the same time that, by the formation and precipitation of oxide of manganese which takes place at all points of the water during its contact with substances of an organic origin, it has the effect of mechanically drawing down impurities held in suspension. Add to this, that water purified by the permanganate of potash, is, in most instances, pure enough for every ordinary purpose, and so charged with oxygen as to be highly agreeable to the palate and beneficial to digestion. When absolutely pure water is required for some special scientific object, it can be readily procured with one distillation by the use of permanganate of potash. If people were only taught the many uses of this valuable salt, not only as a water test and purifier, but as a general disinfectant, it would have a place in every well regulated household in Great Britain and we would hear less of dreadful epidemics, of zymotic diseases.

Having thus considered the action of the alkaline salts of permanganic acid on organic matter, and their incontestable value as qualitative tests for the existence of decomposing matters in solution, I will glance for a moment, at their claims as volumetric tests in the quantitative analysis of water. In com-

mon with many chemists I had, at first, great hopes of their proving a means of greatly simplifying what is at present a very delicate and unsatisfactory mode of estimation, but, I am bound to state, after careful experiment, that I consider they have entirely failed and that for several cogent reasons: viz^t. Firstly — the great errors which arise owing to the presence of protosalts of such metals as iron. I will not now needlessly occupy space by collecting and enumerating my experiments in this direction, suffice it to say, that, the action of permanganate of lime on lead, as already shown, may serve as a type of the action of salts of permanganic acid in the presence of protosalts of peroxidizable metals; and it has therefore, only to be noted that iron in water, though estimated as oxide, usually exists as super-protocarbonate (held in solution by the extra atom of carbonic acid) and the uselessness and impracticability of this volumetric test will easily be made manifest. Secondly — the doubtful nature of the permanganate of potash as a volumetric test may be argued as follows, without reference to the errors above mentioned ¹⁾. Let us suppose two samples of water containing equal weights of organic matter (say M) and that this weight, is so distributed among the elements C, H, N and O, that, in the first case

$$M = pC + qH + rO + sN$$

and in a second case

$$M = p'C + q'H + r'O + s'N.$$

¹⁾ Chemical News.

The permanganate having exerted all its oxidizing power the carbon has become carbonic acid, and the hydrogen, water. O , may then denote the quantity of oxygen required in the first case and O' the amount in the second while P is the number of measures of test solution used in the first case and P' in the second. We shall thus have $PO'' = O$ and $P'O'' = O'$: — making O'' stand for the quantity of oxygen contained in each measure.

The equations will then stand, — in the first case

$$PO'' = (pC \times 2^{2/3} + qH + 8) - rO$$

and in the second

$$P'O'' = (p'C + 2^{2/3} + q'H + 5) - r'O.$$

If the mode of estimation by permanganate be correct, we should have the equation $P = P'$ and consequently $PO'' = P'O''$. A result which is very remote, and which evidently requires the absurd supposition that, whilst the total weight of organic matter remains the same, the four quantities vary so much among themselves, that the quantity of oxygen consumed remains constant. Again suppose, for simplicity, that two waters contain each in an equal bulk 5 grains of organic matter, consisting of carbon and hydrogen only, distributed thus: — In the first case $3\frac{3}{4}$ grains of carbon and $1\frac{1}{4}$ grains of hydrogen; and in the second case $4\frac{2}{7}$ grains of carbon and $\frac{5}{7}$ grains of hydrogen —, the Equations would be —

$$PO'' = 3\frac{3}{4} \times 2^{2/3} + 1\frac{1}{4} \times 8 = 20$$

$$P'O'' = 4\frac{2}{7} \times 2^{2/3} + \frac{5}{7} \times 8 = 17.14.$$

Thus the number of degrees of permanganate used in the first case would be to the number used in the second, as 20 : 17; and it would be inferred that the quantities of organic matter were in this ratio while all the time the weights were equal!

Having thus glanced at the arguments proving the fallacy of carrying the use of the permanganate into the quantitative analysis of water, it only remains to say, that they do not in any way affect the subject in hand, namely, the utility of permanganate of potash as a popular sanitary test, and practical purifier for potable water. In my last communications both to the 'British Medical Journal' and to the 'Chemical News' on this subject I said: 'The presence of the deleterious organic impurities in water, will rarely or never fail to be detected by the addition of permanganate solution. Other less dangerous or innoxious oxidisable matters, as iron, for instance, may no doubt occasionally cause a comparatively inoffensive water to be suspected of being hurtful; but it is barely possible that when really dangerous matter of organic origin is present, the permanganate will allow it to escape detection. It may leave comparatively untouched other organic matters, but these will assuredly be the more sound and stable substances which are incapable of producing the horrible results that are sometimes occasioned by unsound and decomposing matters.'

When iron is present in such quantity as to cause erroneous indications, it will usually be detected

by the palate. The taste communicated to water by even very minute quantities of iron, is one which most people would at once recognize. This source of error being known, nothing is easier, for a person possessed of only a smattering of chemical knowledge, than to determine whether the decoloration arises from iron. But the grand object of a popular water-test, so far as organic matter is concerned, is to afford the public a ready and simple means of detecting and rejecting water that may prove prejudicial to health. This the permanganate test satisfactorily accomplishes. If its use may sometimes lead to the temporary rejection, as unwholesome, of water charged with nothing worse than iron, the mistake will be on the safe side, and can never give rise to injurious results.

The popularisation of the permanganate test would assuredly tend to put an end to the occurrence of those outbreaks of fatal disease which are caused by polluted water; and if this result were obtained at the expense of the occasional rejection of an innoxious water, it would be very cheaply purchased. But, what is more, the popular use of this substance would not only prove an effectual safeguard against those accidents to the public health, which arise from the use of befouled water, but would afford the means of extemporarily purifying such water, and rendering it fit for consumption. Water that has been treated by permanganate will be found to be deprived of putrescible matter. Even repulsively foul water, after

purification by this means, is not liable to become offensive. Permanganate solution, therefore, is not only of great value as a popular test for polluted water but also as a safe and reliable means of freeing potable water from deleterious putrescible matters.

Part II.

Permanganate of Potash as an Air test etc.

The basis of the atmosphere is that mixture of gases which is more particularly understood by the term 'atmospheric air'. This wellknown compound is composed, within a fraction, of four measures of nitrogen and one of oxygen intimately inter-diffused. The circumstance that each of these ingredients preserves its peculiar properties, only slightly modified by the presence of the other, sufficiently proves that they are not chemically combined, but united in the form of a definite admixture. Viewed in reference to the part it plays in the support of life, atmospheric air may be considered to possess the sensible properties of oxygen, which as compared with its other essential element, alone performs the duty of an active principle.

Associated with those fundamental components, are found, in variable proportions, certain other diffusible

bodies which appear to be essentially necessary to the constitution of the atmosphere — namely carbonic acid, aqueous vapour, ammonia and ozone. Of these, carbonic acid, which is the least variable in amount, is estimated by the best authorities to be present in the proportion at most of one part in 1000. The quantity of aqueous vapour contained in the atmosphere, varies from $\frac{1}{3}$ to 2 per cent according to the temperature and other circumstances, such as the more or less aqueous nature of the surface, and the character and amount of vegetation in each locality. Ammonia and ozone are still more variable in quantity; they are found but in very feeble proportions, occasionally so minute as to escape detection. The former which is probably in the state of carbonate, prevails to the greatest extent in the air of populous districts, and in close places often constitutes a very deleterious contamination; the latter is most abundant at a distance from human habitations.

As well as the essential ingredients above mentioned, the atmosphere contains minute portions of all substances susceptible of remaining aëriform at ordinary degrees of heat and pressure, as well as of every matter, whether solid or fluid, which is capable of being dissolved or suspended in the atmospheric mixture. These may be regarded rather as accidental than normal constituents and they constitute for the most part the contaminations of the atmosphere¹⁾.

¹⁾ Comptes Rendus de l'Academie des Sciences v. 37, p. 798.

With few exceptions they are substances of an oxidizable nature. They consist of a great variety of more or less diffusible products, such as the gases generated by combustion and similar processes; traces of nitric, acetic, and sulphurous (or rather sulphuric) acids, of nitrate, acetate, and hydrosulphate of ammonia, and in certain maritime situations, of hydrochloric acid and iodine; exhalations from the organic kingdoms, morbid emanations from men, animals, and plants, when suffering from disease, and the results of their decomposition after death; as well as of numerous forms of more or less tangible solid substances, such as carbonaceous matter, infusoria and other microscopic organisms, pollen of plants, spores and germs of some low orders of living beings, and finely subdivided organic matter. As even the latter group of bodies are invisible to the naked eye in ordinary diffused light, none of the above substances can be regarded as cognizable to the senses except when they naturally possess or happen to acquire odorous properties. They then become perceptibly offensive, and cause the atmosphere in which they exist to be distinguished as 'foul'. It is principally the truly gaseous class of impurities which are possessed of odorous properties, although, on the one hand, some of them, and those not the least deleterious, such as carbonic oxide, are devoid of odour; and, on the other, some of the less diffusible atmospheric contaminations, such as ordinary bodily exhalations, which are not commonly perceptible to the nose, can be distinguished by persons

of more than common acuteness of smell, especially when proceeding from the bodies of the sick. The effluvia which certain wild animals leave on their tracks, and which constitute the 'scent' of the hunting field, afford a familiar example of the latter substances. It has been shown¹⁾ very clearly, that there is no necessary relation between the odorous and deleterious properties of atmospheric impurities, and that mere deoderization is not disinfection. With reference to this point, the elements of morbid animal exhalations and malarious and putrefactive vapours may be classified thus, viz^t:

Dangerous but Modorous	Odorous but slightly offensive	Most offensive, but not infectious
Remittent Miasms	Ammonia	Sulph ^d . Hydrogen
Typhoid Miasms	Carbonate of Am-	Phosph ^d . Hydrogen
Carbonic Oxide	monia	Carburetted Hydro-
Carbonic Acid	Cyanogen	gen
	Sulpho-cyanogen	Sulph. Ammonia.

That the air contains a considerable quantity of tangible matter is clearly seen, when a ray of sunlight happens to penetrate by a small aperture into a dark room. It then becomes evident, that air holds in suspension an infinite quantity of solid particles called 'dust'. This dust is of a very complex character, being composed not only of inorganic matter, but of extremely minute shreds of organised substances derived from the wear of the materials of our clothing and habitations, the articles we eat, the

¹⁾ Leeson on Disinfection 1847.

exuviae of ourselves and domestic animals, and the detritous of plants ¹⁾. In some of the hospital wards in Paris, no less than thirty per cent of organic putrescible matter, which on being moistened exhaled a strong odour of putrefaction was detected by M. Chalvet in the dust found attached to the walls, and as much as 46 % by M. Réveil. This latter gentleman has succeeded in showing, by means of the microscope, that the air of many surgical wards leaves in the aëroscope, epithelial cell turning yellow under the action of nitric acid, and filaments of lint charged with organic corpuscles apparently derived from human discharges, and has proposed to distinguish the air of hospitals by the term ,nosocomial atmosphere' ²⁾.

The researches of Ehrenberg have proved the presence in the air in some localities, of infusorial organisms, as those of L. Pasteur, and others have demonstrated, spores of fungi and germs of vibriones to be of common occurrence in certain atmospheres. It must not however be inferred from such observations, that these microscopic beings are of themselves sources of impurity or capable of reproducing it. On the contrary, they are merely attendants on foulness otherwise derived, and, like confervoid vegetation in water, are, during their processes of life and propagation, sources of the purest oxygen gas ³⁾. Unfitted

¹⁾ Comptes Rendus de l'Academie des Sciences t. 1, p. 1122.

²⁾ Revue Médicale 30. June 1862.

³⁾ Liebig's Animal Chemistry v. 1, p. 216.

for existing except in impurity, they would seem destined by their mode of being, to act as one of the natural means of purification in circumstances of extreme pollution.

To the group of more diffusible contaminations, belong those emanations of effete matter which are constantly proceeding from organized beings and their exuviae, especially during disease, and escaping into the atmosphere. Impurities of this nature are rarely very perceptible to the senses, unless when more than usually concentrated, or in the immediate vicinity of their source. It is probably owing to their presence in the air, that the ammoniacal salts obtained by the evaporation of rain water, which in its fall washes the atmosphere, when tested with lime to set free ammonia, after the addition of an acid, emit an odour most strongly resembling that of corpses, or the peculiar smell of dunghills¹⁾. Even the exhalations which pervade the habitations of men, though of a highly putrescible character, are not, under ordinary circumstances, very cognizable to the senses, except when given off as one or other of the numerous family of volatile alkaline principles²⁾. In cold climates, however, such as Russia, a process goes on during the prolonged winter, which exhibits very clearly the large amount of organic matter diffused in human exhalations. The moisture given off by the lungs and skins of the imprisoned inmates of the

¹⁾ Liebig's Agricultural Chemistry p. 403.

²⁾ Richardson on the blood p. 350.

dwellingings of the lower orders in the north of Russia, is gradually condensed and frozen on the insides of the windows, where it is often allowed to remain undergoing a slow process of putrefaction. On the approach of summer the general than cause the melting of this deposit and the moisture so obtained gives out a strong smell of decomposing perspiration, and the residue, from evaporation, when exposed to heat emits the odour of burning flesh. The announcement made by Dr. Eiselt ¹⁾ of Prague, of his having discovered, by means of the aëroscope, pus-cells in the air of the Orphan Asylum in that city, during an epidemic of purulent ophthalmia, must be considered as tending to prove the occasionally more special nature of the matter by means of which infectious diseases are propagated. We have been prepared the more readily to admit the accuracy of this statement by the experiments of Pasteur on the corpuscles of suppurations.

Air may be deprived mechanically of many of the foreign matters which it holds in suspension, by a process of filtering through finely-carded cotton. Flesh exposed to the action of air so treated, undergoes decomposition much more slowly than in ordinary air, and when decay does supervene, it is unaccompanied by the development of either vegetable or animal life ²⁾. A somewhat similar effect may be

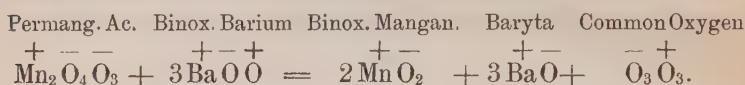
¹⁾ Wochenblatt, Zeitschrift der K. K. Gesellsch. der Aerzte in Wien, No. 13, 1861.

²⁾ Annal. der Chemie und Pharm. t. 119, p. 11.

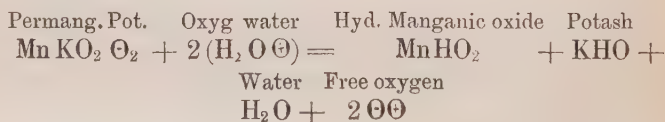
produced by passing air through red hot tubes, which, by the combustion they cause, destroy any organic substances present. Air thus purified, when introduced into grape juice, does not promote fermentation. Similar results have also been obtained from Dr. J. Stenhouse's charcoal air-filters, which combine a mechanical act of filtration with a certain amount of chemical effect, depending on the presence of condensed oxygen in the pores of the carbonaceous matter.

Those who had given attention to the subject, had remarked that the atmosphere contains within itself the means of its purification, and by a process of oxidation, converts all organic substances exposed to it into simpler forms of matter, such as water, carbonic acid, nitric acid etc.; but previously to the announcement made by Professor Schönbein, to the Munich Academy, in May 1840, of his discovery of ozone, it was not understood by what particular agency those impurities were oxidized. The investigations of that distinguished chemist, however, by demonstrating the part played by oxygen in its peculiar condition of ozone, have made plain the nature of the process by means of which this object is accomplished. The result of the action of electricity on oxygen is that a certain portion of it undergoes a process of negative polarization, while another portion is simultaneously transformed into an opposite state of polarity. That portion which is negatively polarized Schönbein distinguished by the name of ozone; to that which is positively polarized the term antozone

has been applied. On coming in contact these two bodies combine and produce ordinary free oxygen. The behaviour of permanganic acid, with peroxide of barium, can only be explained in this way; the super-added atoms of loosely combined oxygen in those two substances, are thrown into opposite states of polarity, and unite to form ordinary oxygen, viz^t:



A still more significant reaction is that of the reduction of ozone, in permanganate of potash, by oxygenated water, for it is certain that one body saturated with oxygen cannot reduce another in a like condition, unless some such polarizing action has produced two modifications of oxygen with an affinity for each other. The action is thus shown: (New notation)



or again ¹⁾



In this tendency to combination between ozone and antozone probably lies the reason why it is found impossible to ozonise more than a limited proportion of any given volume of oxygen, however, long the ozonising process may be continued.

¹⁾ Wurtz.

Some observers have brought forward this circumstance as one calculated to diminish our confidence in the part which ozone artificially produced, is qualified to perform as a disinfecting agent ¹⁾; but when we call to mind that few, if any, of the other so-called disinfectants with the exception of chlorine — itself, after all, possessed on only an indirect action — from which we have been in the habit of forming an opinion respecting the properties of substances used for disinfecting purposes, are truly agents of that nature, we ought to hesitate before admitting the justice of the objection; for it is self evident that extremely minute proportions of a true disinfectant, such as ozone undoubtedly is, must be infinitely more efficacious than much larger quantities of an agent which is possessed of very inferior disinfecting properties.

The wonderful effects of ozone have been moreover explained, and ably illustrated by the experiments of Schönbein, on the properties of oxygen when artificially ozonised, from which it appears that atmospheric air containing only $\frac{1}{3,240,000}$ of that agent, is capable of disinfecting its own volume of air loaded with the miasmata given off, during one minute of time, by four ounces of flesh in a high state of putrefaction, and that an extremely minute portion of ozone is sufficient to bleach a large quantity of sulphate of Indigo ²⁾. It must likewise be borne in mind, that

¹⁾ Hornidge on Ozone.

²⁾ Med. and Chir. Socy. v. 34, p 216.

although the maximum of ozone present at one time in a given volume of oxygen is inconsiderable, its production under the continued influence of electricity or the slow oxidation of phosphorous is uninterrupted, so long as some of that formed is taken up by oxidizable matter. By the introduction of iodide of potassium into oxygen during the process of ozonising, the whole of it may be converted into ozone ¹⁾. Ozone acts on all organized substances, whatever their condition, but its action on organic matter in the fresh or recent state is comparatively feeble; when decomposition has commenced, however, it manifests the utmost avidity for combination with the more oxidizable products which have been or are in the act of being formed. Ozone is in fact the great scavenging principle of nature; and so opposed is it to all foul and effete products of living organisms, that its presence in any locality may be taken as a proof of the absence of those impurities which render the air unfit for use, and consequently as sufficient indication of the state of the atmosphere, with reference to its fitness for the purposes of respiration, and the maintenance of health.

By means of our ozonoscope papers we can, although imperfectly, recognize the quantity of ozone and consequently the degree of purity of the air: — but what shall be done in a case where intemperance, want, uncleanness of person, food or drink, associated as they commonly are with overcrowded dwellings,

¹⁾ Andrews on volumetric relations of ozone — (1860).

have produced a state of concentrated foulness in excess of the normal neutralizing power of the atmosphere, and engendered fever and other zymotic diseases? In such circumstances our ozonoscope is useless, as it is no longer ozone which predominates, but the downward unsanitary scale of organic impurities and a method of investigation based on the employment of some material fitted for marking the variations in the amount of impurities present in the air, is required. By means of an oxidizable substance the presence of ozone in the atmosphere can be detected, and its intensity measured; to indicate the presence of oxidizable impurities in the air, it would, therefore, seem natural to have recourse to some agent containing ozone.

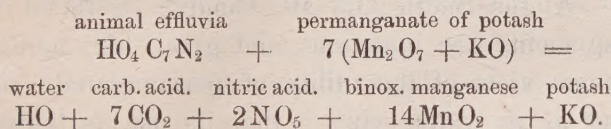
The use in ozonometry of substances liable to change of color by contact with ozone is naturally suggestive of the choice of a body capable of indicating, by somewhat similar appearances, the presence in the atmosphere of substances of a septic nature. From what we have seen of the action of permanganic acid and its salts on impure water it is evident we possess in the permanganates the desired agents. By exposing a solution of permanganate of potash in shallow vessels, the organic matter in the air may be readily detected, and by observing the degree of decoloration produced in the solutions exposed a practical estimate may be formed of its comparative amount.

Although the application of permanganate of

potash to the testing of air is but in its infancy, the scientific principles on which it is based are as certain and reliable as any chemical action. We expose to the air in two different localities of similar temperature, an equal quantity of the same aqueous solution of permanganate of potash, in vessels in every respect alike, and find that in one of them the distinctive color of the permanganate fades and turns to brown twice as rapidly as the other. In order to make sure that the cause does not lie in the vessels but in the medium surrounding them, we change the one for the other and repeat the experiment with fresh portions of solutions of the same strength. Again the progress of decoloration is twice as rapid in one place as in the other. The loss of color could only be occasioned by decomposition of the permanganate, and that decomposition could only be caused by contact with a decomposing agent. There was nothing in contact with the solution in either place, except the vessel containing it and the air. But as the greater rapidity of decomposition which was observed in one of the localities, took place alike in both vessels, it could only be the result of different conditions of the air, and the presence of a larger amount of oxidizable matter in one atmosphere than in the other, must have been the circumstance which constituted that condition. We have seen that of the foreign matters with which the air is liable to be contaminated, there are very few indeed which are not of an oxidizable nature; it is therefore but reasonable

to infer that the decomposition produced in the permanganate solution, was caused by atmospheric impurities, and that the rapidity with which it proceeded, would truly indicate the comparative amount, or the comparative oxidability of such impurities.

But not only is permanganate of potash attracting attention as a popular test for impure air, it is also capable of being used as a purifier of the same. Of the oxidizable impurities which are found in the atmosphere, few are so disposed to combine with active oxygen as the decomposing effluvia which proceed from the morbid and putrefying bodies, and the effete exuviae of men and other animals. When in a condition for combination, their elements form with that substance compounds of a most permanent nature. Assuming those matters to resemble in constitution nitrogenized animal bodies, their behaviour in the presence of permanganate of potash may be represented by the following equation:



Every particle of such substances which thus undergoes oxidation, represents so much unwholesome matter reduced to an inert and innoxious condition, and the quantity of permanganate decomposed will correspond to the amount of impurities destroyed. Were it possible to bring the organic matter, as it exists for instance in offensive exhalations, into rapid and

intimate contact with the permanganate, the process of purification would be instantaneous and complete. This, however is perhaps scarcely obtainable. The destruction and withdrawal of such impurities as obtain contact, must, nevertheless, have the effect of lessening the total amount present, and of improving the average purity of the air acted upon. In the atmosphere of confined places or of localities where the source of the impurity is limited, as in a room containing a few cases of fever or other contagious disease, this result is speedily obtained. The mere exposure of an extended surface of solution of permanganate of potash, will in general suffice to destroy as great an amount of impurity as that which is continually being imparted to the atmosphere.

Several forms of apparatus have been proposed for the application of permanganate to air testing, among the most notable of which may be noted that of Dr. Angus Smith and Mr. Condry. Both of these arrangements are ingenious and good, but, as I hold the same view of the utility of permanganate in air testing as in water, viz — that its use is limited to popular qualitative sanitary testing only — I always advise the following easy method. Take four white stone ware dishes of equal size, and, having previously prepared a solution of three grains of any permanganate (preferably permanganate of lime) in an ounce of distilled water, put an equal quantity of water in each plate (say two fluid ounces). Now

number the dishes respectively 1, 2, 3 and 4. And into No. 1 put one drop of the prepared solution — into No. 2 two drops — into No. 3 three drops and into No. 4 four drops. Set the dishes side by side in the suspected room or building for six or twelve hours and then observe the amount of decolorization in each plate. If No. 1 only be discolored then the air in the room is in the normal condition of a healthy atmosphere, but if No. 2 be affected then the air is tainted; while if Nos. 3 and 4 be discolored the air may be pronounced decidedly dangerous and immediate measures ought to be taken, either in the shape of ventilation or otherwise, for its purification.

Some chemists will smile at the simplicity of the above directions, but, it must be remembered, I am writing of a popular test, to be placed in the hands of utterly unlearned people, and in practise (from many careful observations in the wards of hospitals and other tainted places) I have found the above simple method of testing to give admirably true results. It has been already mentioned that, in my opinion, all the efforts of chemists to apply the permanganates to the quantitative analysis of air will prove fruitless, owing to the reducing action exerted by such agents as sulphurous acid, olefiant gas, or sulphuretted hydrogen, all of which are commonly present in the air of coal consuming districts; but I look upon them, applied as above, as most valuable tests as to the sanitary condition of the air in public

